Multipath effect of MIMO-enabled device in Constrained Environments

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ABSTRACT: The demand for wireless throughput has increased immensely, and high data rate wireless communications is of significance in emerging wireless local area networks (WLANs) and home multimedia networks. Massive data consumption being aided by emerging technologies is helping the demand for wireless throughput to experience exponential growth. Massive data consumption results from high-definition video streaming, automatic software updates, cloud backups, social media autoplay, and background app syncing. Wireless transmission in constrained environments such as a highly obstructed and large network environment is crucial. Thus, designing a very high-speed wireless link that offers good quality-of-service (QoS), the QoS metric such as delay, throughput, latency, packet dropped and jitter, and range capability in NLOS (Non-Line-of-Sight) environments constitutes a significant technical challenge. MIMO (Multiple-Input Multiple-Output) enhances Non-Line-of-Sight (NLOS) communication by using multipath propagation to improve signal reliability, range, and throughput. MIMO-based systems effectively manage the interference and signal attenuation common in NLOS environments, enabling robust communications where single-antenna systems fail. It increases signal reliability through diversity, and boosts data throughput via spatial multiplexing. The coverage is extended by combining reflected signals. MIMO uses reflections off buildings and other objects to create multiple paths, and allows the receiver to reconstruct a stronger signal. Transmitting multiple copies of data across various antennas, MIMO increases signal reliability and mitigates signal drops in constrained environments. The study investigates the effect(s) of multipath propagation on QoS in a MIMO system, using unlicensed spectrum. Research findings indicated that MIMO-enabled device, using multipath effect in the line of transmission, is the best wireless transmission option for a highly obstructed and large network environment as it provides better throughput, high data rate, reliable delivery of data, low delay, wider coverage and easier mobility of users.

KEYWORDS: MIMO, unlicensed spectrum, QoS, home multimedia networks, NLOS, SISO

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I. INTRODUCTION

Multiple-Input Multiple-Output (MIMO) technology evolved from research on multi-channel interference into a cornerstone of modern wireless, leveraging multiple antennas at both ends of a communication link to boost data speeds, which implies that MIMO finds its roots in antenna diversity. MIMO technology uses multiple antennas to transmit and receive the same signal, generating different versions of the same data stream. Receivers in MIMO technology collect a diverse range of signals using a spatial equalizer, and combine them after performing demodulation and decoding. The combined signals is close to the original signal, implying that error is low and data transmission reliability is high. MIMO enhances Non-Line-of-Sight (NLOS) communication by using multipath propagation to improve signal reliability, range, and throughput. MIMO technology has built its system from solely hypothetical performing studies that assured vast capability improvements to genuine inventions for the wireless marketplace (Foschini and Gans (1998)). Though several MIMO systems are yet to be adequately verified under pragmatic propagation environments and thus, their incorporation into actual applications can be believed to be in the embryonic stage. This fact buttresses the significance of substantially profound yet easy-to practice approaches to comprehend and imitate the wireless channel and the fundamental radio propagation (Molisch, 2005). Thus, the shaping of MIMO radio channels has enticed much awareness. Originally, the utmost frequently used MIMO model was a spatially flat-fading channel. This matches to a so-called "affluent scattering" narrowband setting. It was soon comprehended that various propagation atmospheres result in a spatial association. At the same time, concern in wideband technology made it crucial to integrate frequency selectivity. Since then, more state-of-the-art models for MIMO channels and propagation have been presented (Ammar et al. (2021)).

Massive data consumption being aided by emerging technologies is helping the demand for wireless throughput to experience exponential growth. Massive data consumption results from high-definition video streaming, automatic software updates, cloud backups, social media autoplay, and background app syncing. Meanwhile, the quantity of the available electromagnetic spectrum has never increased and or

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expanded. The total physical quantity of the electromagnetic spectrum is a fundamental physical constant covering an infinite, continuous range of frequencies and wavelengths. Thus, two facts are apparent, and they are: first, the need for wireless throughput will increase endlessly; second, the capacity of the accessible electromagnetic spectrum will certainly remain the same.

Wireless communication is different from optical fibre communications in that extra fibre can always be installed, so regardless of the intelligence of optical researchers, there is a belief that future optical demand will continuously be met. On the contrary, there is no straightforward answer for wireless throughput. The essential and perpetual wireless bug is a physical layer difficulty: how to offer ever-increasing full wireless throughput consistently in a specified area (Boccardi et al. (2014).

All recommended resolutions seem to fall into one of three groupings:

i. Utilization of spectrum that is presently unexploited or underutilized
ii. Placement of additional access points, each covering a lesser area
iii. Use of access points with several antennas.

The first two actions as exemplified by millimetre wave technology and minute cells. The third action is known as MIMO (Marzetta, 2015).

Additionally, high data rate wireless communications system, close to 1 Gbps transmission rates, is of attention in emergent wireless local area networks (WLANs) and home multimedia networks. At present, research has shown that WLANs proffer highest rates of 10 Mbps, with 50 to 100 Mbps becoming accessible shortly. Though, 50 Mbps is insufficient when challenged with the demand for greater access speeds fitting to the rise in rich media content and rivalry from 10 Gbps wired LANs. Moreover, upcoming home multimedia networks will reinforce various high-speed high-definition television (HDTV) streams, which require close to 1 Gbps data rates.

Another challenge confronted by WLANs and home networks as well as outdoor wireless wide area network (WWAN) technologies for static and mobile access is non-line-of-sight (NLOS) propagation, which makes arbitrary instabilities in signal level, known as fading.

Likewise, inventing very high-speed wireless links that offer effective quality-of-service (QoS) and range capacity in NLOS atmospheres creates a substantial research and engineering challenge. Disregarding fading for now, in principle, the 1 Gbps data rate prerequisite can be met if the product of bandwidth (measured in Hz) and spectral efficiency (measured in b/s/Hz) equals 10^9. As will be explained later, a diversity of cost, technology, and regulatory restraints make such an instinctive force solution horrible, if not unfeasible.

Earlier it was mentioned that an emergent technology, known as MIMO wireless technology, proffers capacity in attaining 1 Gbps wireless links in NLOS situations a realism and upsurges the spectral efficiency by numerous orders of magnitude, as demanded imminent 5G wireless networks and beyond (Tsoulos (2004)). All these decadences in high-speed wireless network led us to the perception of MIMO technology which uses a natural radio-wave phenomenon called multipath. With multipath, the transmitted information rebounds off walls, ceilings, and other objects, reaching the receiving antenna multiple times at diverse angles and slightly different times. In the past, multipath produced interference and slowed down wireless signals. With multipath, MIMO technology uses various smart transmitters and receivers with added spatial dimension, expanding performance, transmission range and higher energy efficiency, higher spectral efficiency, lower latency and simpler access layer. MIMO upsurges receiver signal-capturing power by aiding antennas to combine data streams arriving from diverse paths and at various times. Smart antennas use spatial diversity technology, which puts excess antennas to effective use. When antennas surpass spatial streams, the antennas can add receiver diversity and enlarge range. Additional antennas typically link to better speeds. Thus, a router (wireless adapter) with three antennas can have a speed of 600 Mbps while another with two antennas has a speed of 300 Mbps. The router needs multiple antennas and has got to completely adopt all pieces of 802.11n to achieve the maximum speed thinkable. Legacy wireless devices use Single-Input Single-Output (SISO) technology. They can just send or receive one spatial stream at a time. To device MIMO, the station (mobile device) or the access point must support MIMO. For the best functioning and range, mutually the station and the AP must support MIMO.

Besides, the investigation has shown that the number of devices accessing network will exceed the populace on earth in 2020, so it will devour more energy. Thus, a green, energy reduction and an environmental guard is an imperative problem in high-speed WLAN, 5G network and beyond. Resource management, allocation and equally QoS is an important aspect to the wireless communication system.

Lastly, looming wireless technologies necessitate vital and crispy thoughtful of design ethics and control systems to professionally operate network resources. Resource allocation plans lie at the core of wireless communication networks since they intend at ensuring the essential QoS at the user level while certifying resourceful and enhanced process at the network level to make the most of operators' revenue. Resource allocation management in wireless communications undoubtedly will comprise a wide spectrum of network functionalities, such as scheduling, transmission rate control, power control, bandwidth reservation, call admission control, transmitter assignment, and handover (Lee et al. (2014).

Demands for imminent wireless communication networks are to offer high data rates, improved QoS whilst sustaining an open architecture for a multiplicity of international standard wireless network technologies ranging from 2G/3G/4G cellular radio systems as Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS) to Wireless Local Area Networks (WLANs), Broadband Radio Access Networks (BRANs), Digital-Video Broadcast (DVB) and Digital-Audio Broadcast (DAB) networks (Jankiraman, 2004). Even though the offered radio spectrum is a scant resource, increasing user demand for extreme bandwidth applications with diverse QoS guarantees over wireless networks has generated an extraordinary

technological challenge to develop effective coding and modulation schemes along with cutting-edge signal and information processing algorithms to advance the quality and spectral efficiency of wireless communication links (Bhushan (2025)).

Furthermore, it is commonly acknowledged that large-scale MIMO is a crucial technology to upsurge the spectral efficiency by numerous orders of size, as demanded future 5th generation wireless networks and beyond (Yang and Hanzo (2015)). MIMO is built on using a hundred antennas concurrently to serve tens of users in a similar time-frequency resource. The variety of huge quantity of antennas infers quasi-orthogonality amid the users' channels in consequence of the law of large numbers. Henceforward, linear transmitters and receivers such as zero-forcing (ZF), maximal ratio transmission (MRT) and maximal ratio combining (MRC) attain great operation (Rusek, 2013). MIMO technology proffers advanced energy effectiveness, sophisticated spectral productivity, reduce latency and straightforward access layer (Zheng et al. (2015)). These advantages cannot be fully utilized without sufficient resource apportionment tactics which expands the Quality of Service (QoS). Thus, researchers have explored this resource apportionment matter with distinct network architectures and theories.

Makki et al. (2016) obtained the least number of transmitting/receive antennas fulfilling outage possibility limitation in point-to- point massive MIMO technology. Yang et al. (2019) initiated a shared antenna choice and user slating policy for downlink massive MIMO technology assuming a restricted number of radio frequency (RF) chains.

Liu. and Lau (2014) considered a combined antenna selection and power-sharing structure that exploits the sum-rate in a big cloud radio access network. A polynomial-time algorithm was recommended by Gkizeli and Karystino (2014) to improve the beamforming path and choose the set of antennas with an utmost signal-to-noise ratio (SNR). Distributed massive MIMO technology with restrained backhaul power are studied by Gouzhen et al. (2014). The antenna adoption issues under an inadequate number of RF chains are also examined by authors, Gao et al. (2013) for calculated massive MIMO channels.

Amadori and Masours (2016) considered a small density antenna choice algorithm based on productive interference for throughput boosting, considering matched filter receiver in downlink massive MIMO technologies.

II. MATERIALS AND METHODS

A. Software Requirements

The software requirements deployed in this article are a network management software called UniFi Controller, an Operating System (Linux, Mac OS X, or Microsoft Windows 7/8/10), Java Runtime Environment 1.6 (or above), Web Browser, A workstation (PC/Laptop) running the UniFi Controller software, located either onsite and connected to the same Layer-2 network, or off-site in a cloud.

B. Hardware Requirements

The hardware requirements are the Transmitter (wireless access point), Receiver, Switch, Router, Laptop, LAN cables. The two transmitter that was used are ubiquity unifi access point long rang (UAP-LR) that support 802.11ac MIMO technology, which is capable of transmitting 867 Mbps data. This provides a wireless signal to mobile users in other to investigate the roaming algorithm. Table 1 shows the detailed specifications of the access point. In this study, iPhone 6, iPhone 7 and Samsung S7 edge, S8 edge mobile phones models as well as various laptops brand are used. The router routes packet to and fro the network and also connect the network to the internet gateway, it also assigns an IP address for the connected users using DHCP. The switch provides access to devices that are connected via wired LAN. The unifi controller will be configured and installed on the laptop for all-inclusive management of the network. LAN cables provide access to the local area network for devices directly connected to the switch and the router. DHCP automatically assigns IP addresses to the wired access point (AP) as well as to the wireless AP after the deployment.

Table 1 Ubiquity UniFi AP-LR Datasheet and Specifications

Parameter	Description
Dimensions	175.7x175.7x43.2mm (6.92x6.92x1.70”)
Weight	240g (8.5 oz)
with mounting kits	315g (11.1 oz)
Networking interface	10/100/1000 Ethernet port
Buttons	Reset
Power method	802.3af/A PoE 24V passive PoE (Pairs 4 5+ 7.8 Return)
Power supply	24V,0.5 Gigabit PoE Adapter*
Power save	Supported
Maximum power consumption	6.5W
Maximum TX power 2GHz/5GHz	22dBm/24dBm
Antennas	Dual-Band Antenna Tri-Polarity 2.4GHz: 3dBi, 5GHz: 3 dBi
Wi-Fi Standards	802.11 a/b/g/n/r/k/v/ac
Wireless security	WEP WPA-PSK, WPA-Enterprise (WPA/WPA2 TKIP/AES)

Parameter	Description
BSSID	Up to 8 per radio
Mounting	Wall/ceiling (kits included)
Operating temperature	-10 to 70C (14 to 158 F)
Operating humidity	5 to 95% Noncondensing
Certifications	CE, FCC, IC, DFS
Environment	Indoor
2GHz MIMO	3x3
5GHz MIMO	2x2
Wireless Uplink	Supported
Advanced Traffic Management	
VLAN	802.1Q
Advanced QoS	Per-User Rate Limiting
Guest Traffic Isolation	Supported
WMW	Voice, Video, Best Effort, and Background
Concurrent Clients	250+
Supported Data Rates (Mbps)	
Standard	Data Rates
802.11ac	6.5 Mbps to 867 Mbps (MCS0-MCS9 NSS1/2 VHT 20/40/80)
802.11n	6.5 Mbps to 450 Mbps (MCS0-MCS23, HT 20/40)
802.11a	6.9 12 18 24 36 48 54Mbps
802.11g	6.9, 12, 18, 24, 36, 48, 54Mbps
802.11b	1 2 5.5 11 Mbps

C. Ubiquity UniFi Access Point Configuration

This configuration is crucial to allow users to connect to have access to the network wirelessly. The steps involved to configure the access point are: A browser is launched to manage the network by clicking on the necessary button, a browser is opened. For a new user to UniFi AP (UAP), there is a need to create a username and password to log into a dashboard and setup the UAP. After Login, as an administrator, the UAP can be setup and, on real-time, manage the UAP.After logging in, on the dashboard, on the right corner is the channels available for use. These include 2.4GHz and 5GHz channels which indicate that the UAP is a dual-band transmitter. Also, at the upper right corner is the name for the access point and the Login account details.Also seen is WAP, type of devices connects to the WAP, how long they have connected, throughput information, the channel used, transmission indicator and the number of the access point that the user is managing (in this figure, only one WAP is being managed, IP address allocated to the device, status of connection (green colour indicates that the WAP is active)).The UniFi dashboard allows network administrator too remotely or onsite install, control, manage WAP. Furthermore, it has added advantages such as a map. Location can be uploaded onto the dashboard via the google map. Also, architecture design or layout design of an area being measured can be drawn using the dashboard.

The tab of how many clients is connected to the WAP device, the IP address allocated to client/user, when connected, uplink and downlink data rate respectively are seen. While on the setting tab, the WAP, password, SSH authentication, wireless network, IP address allocation for clients that are connected, controller settings and update of controller software are setup and configured. Among other changes or configuration that could or need to take place is the changing of the radio channel, download and upload information of all connected devices, type of service being used by the client.

D. Wireless LAN Channels

According to Table 2 (approved tables for wireless LAN channel for US, Europe, Canada and Japan respectively), the approved channels that can be used each separated by 5 MHz are specified. Channel 14 is unused by any regulated body, as agreed. IEEE 802.11 b/g/n supports the above table and it is illustrated using Figure 1.

Table 2 Frequency Channel Plan

Channel ID	Carrier Frequency	US	Europe	Japan	Canada
1	2.412	X	X	X	X
2	2.417	X	X	X	X
3	2.422	X	X	X	X
4	2.427	X	X	X	X
5	2.432	X	X	X	X
6	2.437	X	X	X	X
7	2.442	X	X	X	X
8	2.447	X	X	X	X
9	2.452	X	X	X	X
10	2.457	X	X	X	X
11	2.462	X	X	X	X
12	2.467		X	X	
13	2.472		X	X	
14	2.484		X	X	

simple and one of the most common wireless technologies.

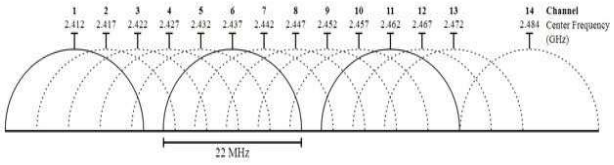


Figure 1 Carrier Frequency of WLAN channel

According to Figure 1, channel 1,6, and 11 are the only non-overlapping channels. The effect of using each channel would be investigated and, the best channels that are visible to users would be proffered.

III. RESULTS AND DISCUSSION

Consistent network performance has long been a significant aspect of many network applications. Investigation and performance analysis of the QoS in MIMO wireless technology and the QoS metric such as delay, throughput, latency, packet dropped, and jitter are the objectives of this study.

To evaluate the performances of the MIMO wireless system technology, the analysis was based on verifying the packet sent, the packet received, and packet dropped, using the following tools: ping command in windows operating system, MikroTik router board, R package and Ubiquiti UniFi controller.

The analysis was performed varying the number of users (1 to 20). The metrics used for the performance comparison include Packet Dropped (packet), Delay (sec), Round Trip (ms), Traffic Load (bits/sec), and Throughput (bits/sec). A graph was plotted for each analysis done using the user-friendly graphical interface of R package. The screenshots of these graphs form the basis of analysis.

Spectrum analysis carried out before (Figure 2) and after (Figure 3) the deployment of a MIMO-enabled AP shows significant differences in how RF energy is utilized, distributed, and managed within the given space. The core changes center around increased spectral efficiency, reduced interference through spatial multiplexing, and optimized coverage. Before MIMO, spectral analysis shows lower utilization efficiency. After deployment, the MIMO AP uses spatial multiplexing to send multiple data streams simultaneously on the same frequency channel, which translates to higher data rate per Hz in the spectral plots. The spectrum analysis carried out after the deployment of the MIMO-enabled AP reveals that MIMO uses multipath propagation to enhance data reliability and throughput, resulting in a cleaner, more efficient signal reception at the receiving end.

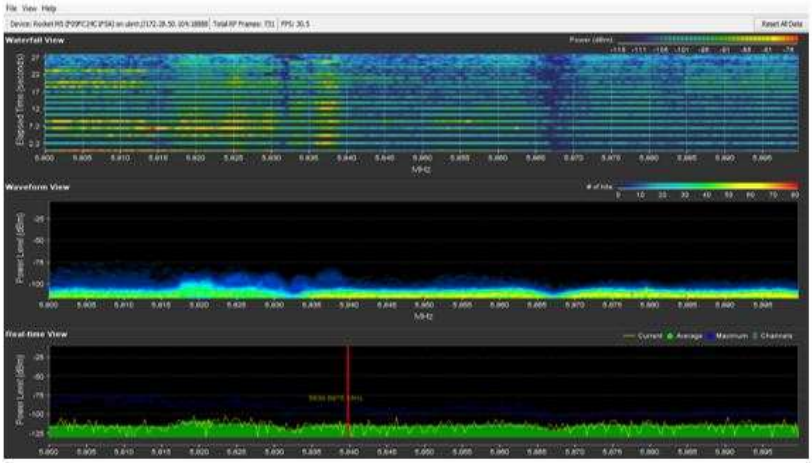


Figure 2 Spectrum Analysis carried out before the deployment of the MIMO-enabled AP.

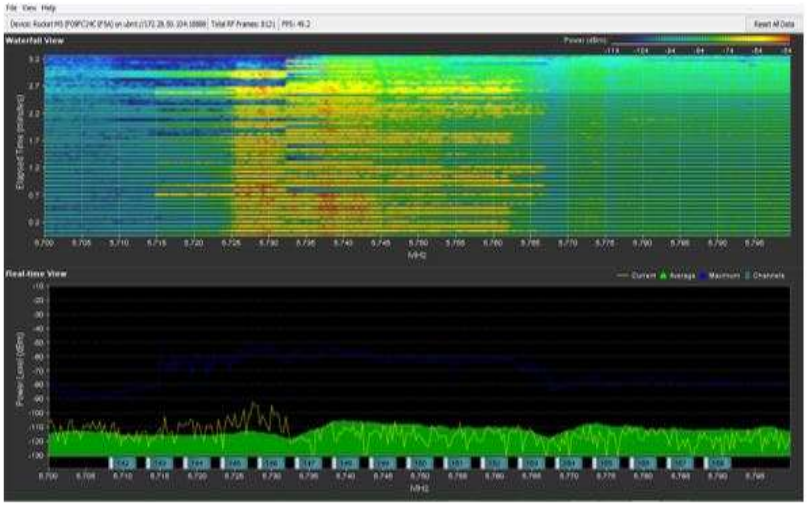


Figure 3 Spectrum Analysis carried out after the deployment of the MIMO-enabled AP

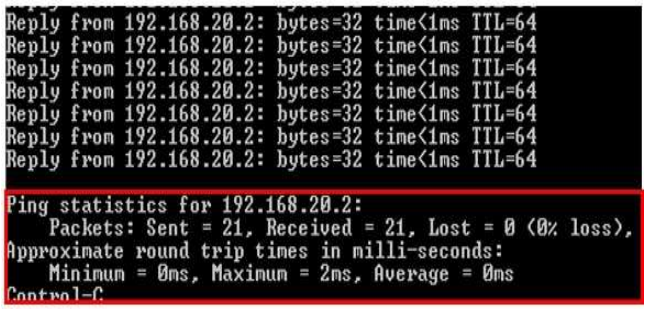


Figure 4 The delay, the packet sent, the packet received, the packet dropped deployment of the MIMO-enabled AP, and the Round-Trip time after the deployment of MIMO-enabled AP.

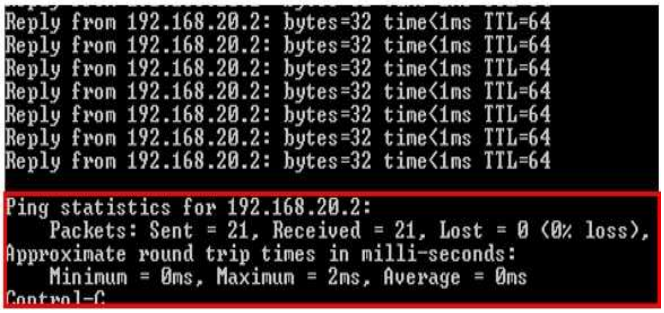


Figure 5 Second Ping did for the delay, the packet sent, the packet received, the packet dropped and the Round-Trip time after the deployment of MIMO-enabled AP

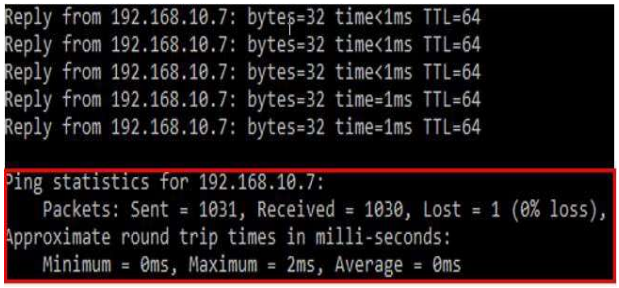


Figure 6 Third ping statistics for the delay, the packet sent, the packet received, packet dropped and Round-Trip time after the deployment of MIMO-enabled AP.

Spectrum analysis before and after deployment MIMO-enabled AP (Figures 7-10) reveals that MIMO improves throughput by utilizing spatial multiplexing to send different data streams simultaneously on the same frequency. MIMO enables higher data rates within the same spectrum. Throughput gains from MIMO are particularly high.



Figure 7 Throughput obtained from the First analysis. (a) Spectrum analysis after deploying MIMO-enabled AP. (b) Spectrum analysis before deploying MIMO-enabled AP



Figure 8: Throughput gotten from the Second analysis. (a) Spectrum analysis after deploying MIMO-enabled AP. (b) Spectrum analysis before deploying MIMO-enabled AP

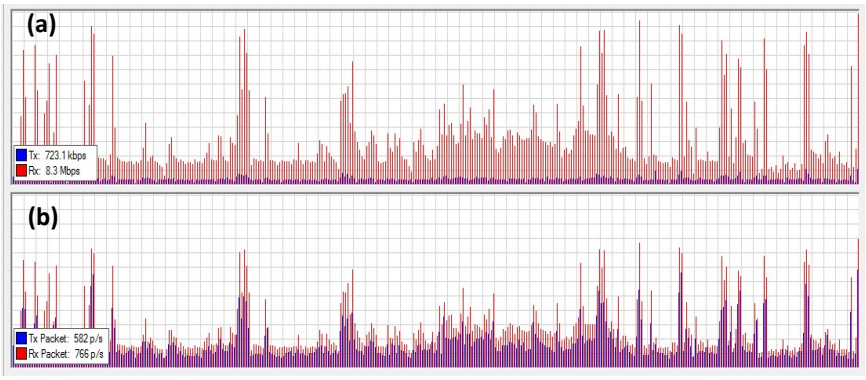


Figure 9 Throughput gotten from the third analysis. (A) Spectrum analysis after deploying MIMO-enabled AP. (B) Spectrum analysis before deploying MIMO-enabled AP

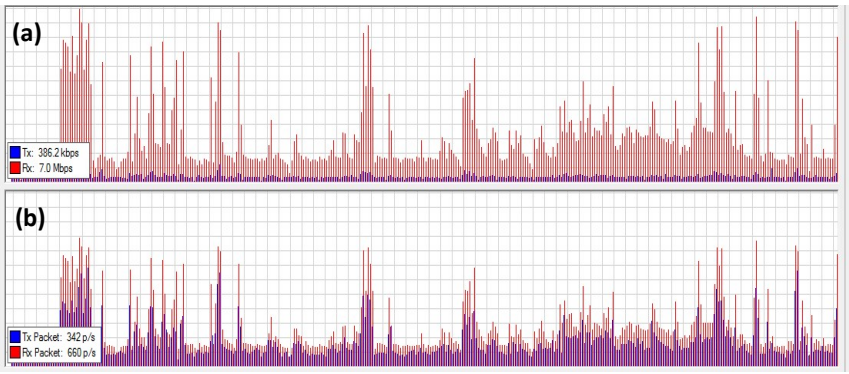


Figure 10 Throughput gotten from the fourth analysis. (A) Spectrum analysis after deploying MIMO-enabled AP. (B) Spectrum analysis before deploying MIMO-enabled AP

Table 3 Summary of Ping Results

Obstacle Nodes	Packet Sent (bit/sec)	Packet Received (bit/sec)	Packet Loss (bit/sec)	Round Trip Time (ms)	Average Round Trip Time (ms)
1	152	152	0	1	2
2	180	180	0	1	2
3	298	298	0	1	2
4	298	298	0	1	2
5	299	299	0	1	2
6	2358	2358	0	1	2
7	1031	1031	0	1	2
8	207	207	0	1	2
9	1879	1879	0	1	2
10	1638	1638	0	1	2
11	1800	1800	0	1	2
12	2500	2500	0	1	2
13	3000	3000	0	1	2
14	3500	3500	0	1	2
15	4000	3800	0	2	2
16	4800	4600	0	2	2
17	5200	5000	0	2	2
18	5800	5600	0	2	2
19	6900	6600	0	3	2
20	8800	8500	0	3	2

In the Table 3 is shown the performance comparison of the metrics used. The metrics include Packet Dropped (packet), Delay (sec), Round Trip (ms), Traffic Load (bits/sec), and Throughput (bits/sec).

Though, it is impossible to guarantee that 100% of packets sent are fully received without a single drop across all nodes over any significant period, however, it is possible briefly in highly controlled environments, like a highly controlled LANs/WLANs (as in this study) or simulated environments where all parameters are under absolute control. It is known that the modern infrastructure makes zero packet loss a design goal, yet practical limitations make occasional packet drops inevitable

Table 4: Summary of Throughput Results

Obstacle Nodes	Throughput (Mbps)	Obstacle Nodes	Throughput (Mbps)
1	18.39	11	15.55
2	18.20	12	14.69
3	18.10	13	14.44
4	18.00	14	14.00
5	17.98	15	12.93
6	17.87	16	12.82
7	17.40	17	12.40
8	16.97	18	12.80
9	16.60	19	12.60
10	16.20	20	12.20

Throughput results for MIMO-enabled AP operating through obstacle nodes (Table 4) show significant improvements since MIMO leverages on obstacles to create additional signal paths, thus, increases network throughput. MIMO uses reflections from obstacles to create multiple paths to increase overall throughput. Delay, packed dropped, throughput and latency are deeply interconnected, and they are the pillars of the network performance analysis in this study.

A. Delay

Transmission delay in a MIMO system refers to the time taken to transfer data from the transmitter (Tx) to the receiver (Rx). The end-to-end delay is the average delay faced during transmission of packets from the source to the destination. Figure 11 shows the graphical representation of the delay encountered between Tx and the receiver Rx

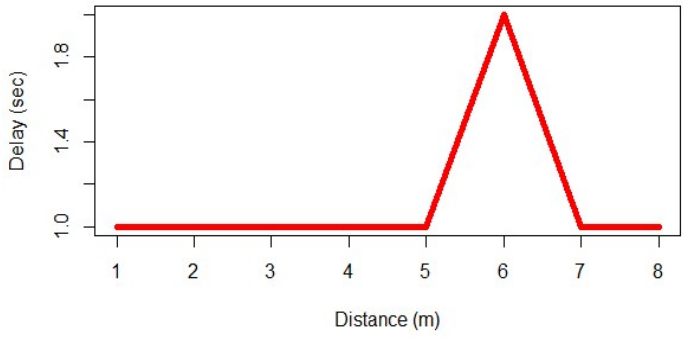


Figure 11 Transmission Delay from the MIMO Tx to the MIMO Rx.

Table 5 Summary of the Delays (sec)

Delay (sec)	Distance (m)	Delay (sec)	Distance (m)
1	1	1	4
1	2	1	5
1	3	2	6

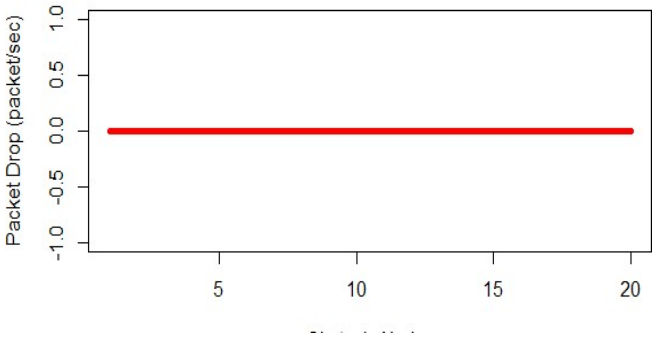


Figure 12 Packet Drop from the MIMO Tx to the MIMO Rx

B. Packet Dropped

Packets are dropped during data transmission due to contact failing retransmission. However, the study shows that there is no packet drop during data transmission with MIMO-enabled AP and receiver (Figure 12). Figure 12 shows the graph of the performance and evaluation of the MIMO-enabled AP and receiver with varying number of obstacle nodes.

C. Throughput

Throughput is the number of packets that are delivered successfully from the sender to receiver; it is measured in bit per second or data packet per second. Figure 13 shows a graph of the performance of the MIMO-enabled AP. From the graph, it can be deduced that MIMO-enabled device still perform effectively despite there are obstacles and interference.

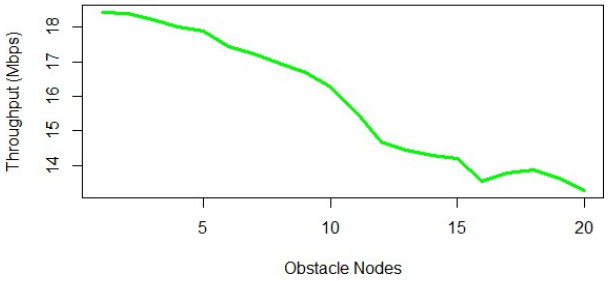


Figure 13 Maximum Throughput Obtained Against the Obstacle Nodes

D. Latency

Latency is the round-trip time taken for the packet to get to the receiver and to send back an acknowledgement to the sender. Figure 14 shows the graph of the latency from the AP to the receiver with obstacles in between the line of transmission. In Summary, having introduced MIMO wireless system technology, it was observed that when a device is MIMO-enabled, it performs better constrained environments such as areas with physical obstacles (buildings and other objects) and highly densified environment. The latency to the AP is low compared to the Non-MIMO-enabled device. Furthermore, users experience high throughput and low delay while transmitting data faster (Table 6).\

Table 6 Summary of the QoS Metrics

Obstacle Nodes	Throughput (bit/sec)	Latency (ms)	Packet Dropped (packet/sec)
1	18.39	1	0
2	18.20	1	0
3	18.10	1	0
4	18.00	1	0
5	17.98	1	0
6	17.87	1	0
7	17.40	1	0
8	16.97	1	0
9	16.60	1	0
10	16.20	1	0
11	15.55	1	0
12	14.69	1	0
13	14.44	1	0
14	14.00	1	0
15	12.93	2	0
16	12.82	2	0
17	12.40	2	0
18	12.80	2	0
19	12.60	3	0
20	12.20	3	0

IV. CONCLUSION

From the experiments and analysis carried out, the performances of MIMO-enabled wireless transmitter and receiver device based on metrics (Packet Dropped (packet), Delay (sec), Round Trip (ms), Traffic Load (bits/sec), and Throughput (bits/sec)), it was deduced that MIMO-enabled device, using multipath effect in the line of transmission, was the best wireless transmission option for a highly obstructed and large network environment as it provides better throughput, high data rate, reliable delivery of data, low delay, wider coverage and easier mobility of users. MIMO uses reflections from obstacles to create multiple paths to increase overall throughput and reduce packet drops to zero (Figure 12). Incorporating MIMO technology, maximum throughput is obtained against the obstacle nodes (Figure 13). Latency from the AP to the receiver is low despite there are obstacles in between the line of transmission (Figure 14).

AUTHOR CONTRIBUTIONS

O. A. Tiamiyu: Conceptualization, Methodology, Software, Validation, Writing – original draft, Writing – review & editing.

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